data may not be exactly correct, as printed below, for I write them down from memory; but they are essentially right.

Photometer.	Telescope.	Star of	Time to Make Observation.	Probable Error of One Determination.
Electric-cell	5-inch	5th mag.	2 min.	± 0.003 mag.
Selenium	12-inch	2nd mag.	60 min.	± 0.01 mag.

A few days following the Hamburg meeting I had the opportunity to see GUTHNICK'S photometer attached to a small refractor, and to learn of some remarkable results obtained on certain interesting stars, but it is not for me to describe them.

If the electric-cell photometer, attached to small telescopes, can measure the light of a fifth-magnitude star, in a few minutes, with an accuracy of a few thousandths of a magnitude,—and this on the first trials of the instrument,—we are entering a new era in the study of the variable stars. The conspicuous difficulties may lie in the variable transparency of our atmosphere, or in the variable brightness of comparison stars. It may in fact be found that the star of constant brightness is the exception and not the rule. The electric-cell photometer may become as important a tool as the spectroscope and dry plate are.

August, 1913.

REVIEW.

By EDWIN B. FROST.

STELLAR MOTIONS, with special reference to motions determined by the spectrograph: The Silliman Lectures, delivered at Yale University by WILLIAM WALLACE CAMPBELL, Sc.D., LL.D., Director of the Lick Observatory, University of California. New Haven: Yale University Press, 1913. 8vo. Pp. 328, with numerous illustrations. Price, $4.00 net.

The value of endowed lectureships is fortunately not limited to the casual auditors or to the institutions in which they are given, however useful the stimulus of the presence of the guest from without may be to hearers and institutions. The lecturer

himself is often a chief beneficiary, as a definite engagement may induce him to halt his work of observing long enough to make the necessary summaries and generalizations for his course of lectures. The general and special public gets its benefit when the lectures are printed and thus reach their widest circle of influence.

The temptation is strong indeed for a busy worker in a new and broadening field to continue to collect all the possible data in his laboratory with a view to furnishing an adequate basis for subsequent conclusions. The necessity of pausing to take account of stock and to draw preliminary inferences may, however, lead him to new inductions, more important than he may himself realize at the outset.

The officers of Yale University charged with providing for the course designated as "The Mrs. Hepsa Ely Silliman Memorial Lectures" were fortunate in choosing as lecturer Professor Campbell, Director of the Lick Observatory. Thus was insured an authoritative presentation of methods and results in one of the most important branches of modern astronomical research, for which most of the data was available on the spectrograms already obtained by the Lick Observatory in the effective campaign planned and executed by Campbell during the previous fifteen years.

The time was also particularly appropriate, as the feeling was developing among some astronomers that enough spectrographic data had already been collected to permit some reliable generalizations as to the motions of Sun and stars. Other investigators were taking up the subject, but none with data at all comparable with the rich material of observation in the possession of the Lick Observatory.

The lectures, eight in number, were delivered between January 24 and February 4, 1910. The preface is dated June 1, 1912, but the volume did not appear from the press until a full year later. This interval gave the author opportunity to refer in occasional footnotes to some of the interesting matters developing in the meantime. Each lecture constitutes a chapter in the book, averaging about forty pages in text.

The introductory chapter gives an excellent historical statement, especially referring to the development of the Doppler-

Fizeau principle of determining the linear velocity of celestial objects from the shifts of the lines in their spectra. It is interesting to note here that FIZEAU's lecture in 1848, in which the principle was first stated correctly, was not published until twenty-two years afterward, so little was its subsequent importance foreseen. A brief outline follows of the simple theory of spectroscopic measurements, and then is given a short discussion of the various types of stellar spectra.

The second lecture deals with the development of the photographic method, the requirements for accurate results, the proofs of the correctness of the observed motions, and the conditions other than those of motion which may affect the position of spectra lines. Proper emphasis is placed upon the immense advance made when photography was successfully applied in 1888 by VOGEL and SCHEINER at Potsdam to the spectroscopic measurements of motions in the line of sight. The next steps of progress were due to CAMPBELL in his design of the Mills spectrograph (1895-6) and his working out of methods of reduction of the spectrograms whereby the best stellar lines were utilized whether or not matched by comparison lines. The spark between iron electrodes was regularly used as source for the comparison spectrum (as originally suggested by VOGEL and so used by him for *Sirius*). Attention was paid to many small details of adjustment and observation, and a surprising and even unexpected accuracy was attained with the first "Mills spectrograph." This instrument certainly was fortunate in its prisms and other optical parts, for the definition has not been improved upon, for the brighter stars, by the later spectrographs designed at the Lick Observatory,—the instrument for Chile (1910) and the "New Mills" spectrograph (1902). The newer design, tending to eliminate flexure for longer exposures, extended the same accuracy (for a dispersion of three prisms) to the stars as faint as visual magnitude 5.0. In this chapter the student will be assisted by the quotations made from CAMPBELL's earlier papers, relative to his method of reduction of spectrograms, to the derivation of planetary velocities from the American Ephemeris by interpolation, and to the computation of the Earth's velocity in the direction of a star.

Chapter III treats of rotational velocities in the solar system and of the radial velocities for individual stars, the first topic including a short reference to the spectroscopic observation of the solar rotation and a fuller account of similar work on the planets. KEELER's classic paper in the first volume of the *Astrophysical Journal,* demonstrating the rotation of *Saturn's* rings, is quoted from at some length. Under the second topic are cited the observed values of separate plates of stars of different spectral types and of different magnitudes, chiefly from Lick results. The examples selected show remarkably good accordance. The effect of the solar motion is well exhibited to the general reader by the grouping of twenty-five velocities in the vicinity of the vernal equinox, of twenty-five near the autumnal equinox, and similarly for the region of the apex of the Sun's way near the constellations *Hercules* and *Lyra,* and for the region of the antapex. The stars' names were not given, consistently with the author's policy of not publishing individual values before the author's general studies upon them and generalizations from them could be completed with sufficient data.

Lecture IV deals in a clear and interesting manner with the solar motion as determined from stellar proper motions across the line of sight and with the systematic or "stream" motions of the stars. Of yet more interest is the following lecture, on the spectrographic determination of the solar motion, which was one of the main objects of the 10-years' campaign at Mount Hamilton and Santiago for radial velocities. A clear statement is given of the advantages of using the motions in the line of sight, but the author very justly adds: "However, the greatest value of radial velocities lies not in their advantage over proper motions, but in aiding proper motions to come into their own strategic worth." The simple procedure is given for deriving the right ascension and declination of the apex, and the solar velocity. Emphasis is properly placed on the difficult part of statistical investigations of this sort,—namely, the assignments of the proper weights for different stars and the possible rejection of stars in groups having parallel motions. This opens the way for a short story of the work (chiefly by LUDENDORFF) on the bright stars in *Ursa Major* and their

traveling compaions, called by our German friends the "bear family"; and leads to the description of the remarkable discovery by the lamented LEWIS BOSS of the *Taurus* swarm. As to the highly important results of the author's work we may state that his early solution in 1900, based on 280 stars (chiefly northern), gave for the apex: $\alpha_0 = 277°.5$, $\delta_0 = +27° 26'$, $V_0 = -17.8^{km}$ per second, which is in good but not perfect agreement with the position from the proper motions now rather generally employed: $\alpha_0 = 270°$, $\delta_0 = +30°$. The two kinds of determinations rest of course upon quite different data, although including all well measurable types of spectra.

It is difficult to discriminate between these absorbingly interesting topics. But, perhaps, the sixth lecture, studies of the stellar system, will bring to the reader the most that may be new to him. Here is brought out the author's important discovery of the relation between radial velocity and spectral type, a subject upon which others were independently at work, notably KAPTEYN.[1] The credit for the discovery of an important principle like this is not at all impaired by its simultaneous and independent detection by another investigator.

In Table XII 1,060 stellar velocities are tabulated, after being freed from the effect of the solar motion, according to their amount (e. g. from 0 to $+5^{km}$, $+5$ to $+10^{km}$, etc., between the limits of $+80°$ and $-80°$) and in two columns, the first for stars of SECCHI'S type I (Draper Classification, B to F4) and the second for SECCHI'S type II (Draper, F5 to M). The table shows plainly the greater residual (or "average" or "peculiar") speed of the stars of type II. Table XIII brings out in more detail an interesting positive residue, for the mean of these velocities, particularly for classes B to B9, for which it amounts to 4.9^{km}. The inference is that the radial velocities of helium stars are for some reason measured too large, positively, by nearly 5^{km} per second. The author discusses several possible explanations of this discrepancy, and concludes: "Of all the

[1] In a paper dated January, 1910, published in the *Astrophysical Journal* for April, 1910 (**31**, p. 260), KAPTEYN gives a table showing the progression of the peculiar radial velocity with type (from B to Ma) as inferred from about 200 stars whose radial velocities were available to him. He allows himself a little speculation as to the cause of "the phenomenon of the increase of velocity with the evolutional stage of the stars." He asks, "Is it not *as if* gravitation had no effect on the cosmical matter in its primordial state?"

explanations suggested, that of a pressure effect in the extensive atmospheres of Class B stars appears to be by far the most probable one," an opinion probably now shared by most others concerned with this matter.

From this difference in the average velocities for SECCHI'S first and second types; from the fact that the 280 radial velocities published by himself in 1901, chiefly of stars of types G, K and M, averaged 17.06^{km}, while twenty helium or B stars, observed elsewhere, averaged only 7^{km}; and from a preliminary tabulation of about sixty stars of class M, yielding about 17^{km} per second, CAMPBELL was able to state: "The progression of average velocity with advancing spectral type is clear and unmistakable."

A year after the delivery of the lectures fresh determinations of the solar motion were made, based upon nearly 1,200 stars, and fourteen solutions are given in Table XV, the different spectral types being treated separately. The constant K, or the apparent correction required for systematic error, is derived for all but one of the solutions, amounting to $+ 4^{km}$ (as already stated) for type B and for type M, to about $+ 1.0^{km}$ for A stars, to 0 for class F and G, but to about $+ 2^{km}$ for class K. The value of V_0, the Sun's speed, comes out about 20^{km} from the B stars, 17^{km} from the A stars, 15^{km} for the F and G stars and 21^{km} for the M stars; the author infers that "V_0 appears to be a function of the spectral class upon which it rests, at least as far as the brighter stars are concerned." This lecture concludes with a discussion of the average distances of the stars as derived from the relations of radial velocities and the proper motions, according to KAPTEYN'S procedure, which is clearly stated. The radial velocities are also given in this chapter for eighty-eight stars with proper motions greater than $0''.50$, tabulated with reference to KAPTEYN'S preferential vertex.

Chapter VII is devoted to the binary stars and naturally is chiefly occupied with spectroscopic binaries, from which no stellar spectroscopist can or would escape. The treatment is clear, and many interesting conclusions are drawn from this comparative study of these binaries and their orbits; the main points have been available to readers since the "Second Cata-

logue of Spectroscopic Binaries," by CAMPBELL appeared in 1910.

Chapter VIII treats of the variable stars, of course chiefly with respect to their radial velocities. Except for the eclipsing systems, there remains much to be explained regarding these bodies, but the known facts are brought out with the author's usual discrimination and judgment, and will hold the attention of even the untechnical reader.

While many of the topics, particularly of chapters VI and VIII, have been discussed by the author in the Lick Bulletins since the date of these lectures, the presentation given in this well-balanced volume will be found of the greatest value and convenience alike to those familiar with spectroscopic work and to those engaged in other astronomical or physical researches, as well as, and particularly, to college teachers of astronomy.

The typography of the book is excellent, and the proofs were evidently read with much care. Clearness would have been gained by the use of sub-heads in the chapters; but the changing running heads of the pages partly supply this deficiency. The numerous half-tones are fairly good, but they fail to do justice to the excellence of the originals, particularly in case of the stellar spectra. They should have been printed on a more suitable paper, as inserts; lighter paper could then have been used for the text, and the illustrations could then have been placed near the text describing them. They are without plate numbers and scattered at random through the book: in fact, one gets the impression that the printer failed to consult with the author on this matter. But these are only minor defects of a remarkably valuable book.

YERKES OBSERVATORY, November, 1913.